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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

QUALITY CONTROL WITHIN THE
NAVAL SUPPLY SYSTEM

by

John Edward Flanagan, Jr.

March 1981

Thesis Advisor: C. F. Taylor, Jr.

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Quality Control Within the Naval Supply System

by

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Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

The implementation of a Naval Supply Systems Command Quality Control Program is intended to promote improved performance at U.S. Naval stockpoints. This paper examines current quality control procedures, compares current practice to quality control theory, and recommends that sequential sampling techniques be adopted. Sequential sampling plans and their associated operating characteristic curves and average sample number curves are provided. Implementation of the recommended procedures would result in a more flexible and efficient Quality Control Program at Naval Supply System stockpoints.

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I. INTRODUCTION

Quality control is recognized as one of management's best and most effective tools in controlling and/or detecting causal variation in a process. The Naval Supply Systems Command Headquarters, realizing the merits of quality control, instituted a Quality Control Program for its stockpoints by prescribing quality objectives for certain material flow functions and process times.

The purpose of this paper is to examine these NAVSUP Quality Control procedures, to assess their validity in light of existing sampling theory, and to recommend, where appropriate, improvements within the limits of available personnel resources.

The overall objective is to provide a program for use by Naval stockpoints that is both practical and efficient, and which will enable stockpoints to enhance and improve their internal performance, thus resulting in better service to the fleet. Five sampling plans with their associated operating characteristic (OC) curves and average sample number (ASN) curves are proposed which will allow a flexible implementation of quality control programs at Naval stockpoints.

The material in this paper is presented in five sections. Section II develops the background information necessary for a basic understanding of statistical quality control. Areas discussed include the objectives of quality control, sampling

strategy to be used, the concepts of the consumer-producer relationship and operating characteristic curves, an explanation of attributes sampling techniques, and determination of an estimate of and confidence interval for proportion defective. In addition, there is a brief development of Department of Defense policy on quality control.

Section III discusses the current NAVSUP Quality Control Program for both material flow and process times, while Section IV proposes new procedures utilizing sequential analysis. Section IV also describes how to apply a specific sequential sampling plan and how to develop a complete quality control program at Naval stockpoints.

In Section V a comparison is made between the current and proposed quality control programs. Section VI contains the conclusions and recommendation of this paper. Finally, the actual sampling plans, OC curves, and ASN curves are given in the Appendix.

II. BACKGROUND

A. OBJECTIVES OF QUALITY CONTROL

The main objectives of quality control are to determine and eliminate causes for errors and to establish control of the quality of the process in order to prevent unsatisfactory output from that process. For quality control purposes, a process is defined as the employment of materials, equipment, and/or men for the purpose of production. Quality control is primarily concerned with determining the capability of a process to meet established standards.

In any process in which material is expected to conform to an established standard, variations in the material output from the process occur. It is the objective of quality control to detect changes in a particular process by observation of these variations. If there is an unexpected variation in the system process average as detected by inspection, then the variation is likely due to presence in the system of some assignable cause, such as a change in personnel or work method. Once this assignable cause is detected, corrective action can be taken to improve the quality of the process.

Acceptance sampling is commonly used in industry and government to discover variations in material output from a process. Acceptance sampling is concerned with the acceptance or rejection of an entire lot based on the results of a sample taken from that lot. With this type of sampling, a

number of units from each lot is inspected. If the amount defective is less than a prescribed minimum, the lot is accepted; if not, the lot is rejected as being below standard. Acceptance sampling can be performed in any situation where there is a consumer-producer relationship as described in Section II.D. Close adherence to standards means fewer defects, and a savings of costs which would otherwise be required for reworking material processed incorrectly.

Acceptance sampling plans are used by the U.S. Navy at its stockpoints in order to control the flow of requisitions and material within the supply system. A stockpoint is a supply center or depot whose primary functions include the issuing, stocking, and receiving of material. The operation of Navy stockpoints is a highly complex system from receipt of material from suppliers and receipt of requisitions from customers, to the issue of material to these customers. Increased emphasis or quality assurance throughout each segment of the operational cycle of a stockpoint is required in order to provide service to the fleet in the most economical way possible.

B. SAMPLING INSPECTION STRATEGY

The primary objective of taking samples from a population is to learn something about that population upon which a decision can be based. In order to ensure that the sample selected from a lot is representative of the whole population, it is essential that the sample be drawn in a random manner.

Randomness implies that every item in the lot has an equal chance of being selected. Because of the difficulties of random selection in large lots, it is advisable to adopt stratified or proportional sampling. In stratified sampling the size of subsamples from each sublot is proportional to the sublot size, and sampled items are drawn randomly from all parts of each sublot of the inspection lot. This grouping seldom has a significant effect on the theoretical behavior of the sampling results as manifested by the OC curve. Grant [Ref. 1] For a more detailed discussion of stratified sampling see Raj [Ref. 2] and Cochran [Ref. 3].

Another consideration in sampling inspection is that each lot inspected be homogeneous, that is, each lot should represent as nearly as possible the output from one process during one interval of time, so that all material in the lot is turned out under essentially the same conditions.

There are several advantages to sample inspection when compared with 100 percent inspection. First, sampling is more economical since there are fewer items inspected. Second, there is less handling damage during inspection. Third, fewer inspections are required which requires fewer personnel. The fourth and probably most significant advantage of sampling inspection is that it creates pressure for quality improvement, since entire lots are rejected rather than individual defectives. This is likely to result in the submission of better quality material for inspection.

C. DOD QUALITY ASSURANCE POLICY

The primary implementing directive for Department of Defense Quality Assurance Policy is DOD Directive 4155.1 of August 10, 1978 with Change One incorporated. It states: "DOD components will plan and implement a quality program as an integral part of all phases of the acquisition and support process and will conduct quality audits to assure the attainment of quality products and services."

SECNAVINST 4855.1 of September 10, 1979 implements DOD Directive 4155.1. There the Chief of Naval Material is designated to ensure compliance with the provisions of DOD Directive 4155.1 and to develop and issue supplemental policies and instructions.

NAVMATINST 4855.1A of January 24, 1974 designates systems commands to formulate quality assurance programs consistent with the quality assurance directives cited above. In compliance with those directives NAVSUP must provide sampling plans and procedures as appropriate to ensure the adequacy of inspections at all stages of the material life cycle.

D. CONSUMER-PRODUCER RELATIONSHIP

When acceptance sampling is used, there is generally a conflict of interest between the consumer who specifies standards of conformance and the producer who produces the material for the consumer. Within the Naval Supply System, a consumer-producer relationship exists between the Naval Supply Systems Command, which establishes material flow and

process time standards, and the Naval Supply Center (NSC), which ensures that NAVSUP standards are attained throughout the operational cycle of receiving, storing, and issuing material.

The NSC in effect is the producer of a product, i.e., service to the fleet. The NSC samples its own performance using sampling procedures and reports its findings quarterly to NAVSUP. NAVSUP then acts on behalf of the consumer and decides from the quarterly reports whether the NSC product is acceptable in meeting NAVSUP-established standards. If prescribed standards are not met, the lot (i.e., the NSC's performance) is "rejected" as substandard. Although this rejection is more figurative than literal, it carries sufficient stigma that such action should not be taken lightly.

The consumer wants a sampling plan which will reject lots with their percentage defective above a certain level called the lot tolerance percentage defective (LTPD). LTPD is defined in Robertson [Ref. 4] as the incoming fraction defective that the consumer is willing to accept with a very small probability of occurrence. The LTPD is a numerical definition of "bad" quality and is commonly designated by the symbol p2. If the plan accepts too many lots above the LTPD, the quality of material will be unsatisfactory. The consumer's risk, designated by β, is the probability of acceptance of a "bad" lot. β is commonly chosen as 0.10. This means that in the long run, only one lot in ten of quality p2 will be

accepted. This is generally sufficient protection to the consumer, since producers cannot afford to have nine out of ten lots rejected, as would occur if the actual quality of the material were as poor as p2.

The producer wants a sampling plan which will accept lots of satisfactory quality called the acceptance quality level (AQL). The AQL is defined as the maximum percentage of defects that is acceptable as the process average, or the long run average quality of items submitted for the purpose of sampling inspection. The AQL is a numerical definition of "good" quality and is commonly designated by the symbol p1. If lots of better than p1 quality, i.e., those with AQL less than p1, are rejected, this means unwarranted rejection. The producer's risk, designated by α, is the probability of rejection of a "good" lot. α is frequently chosen as 0.05. Since the probability of rejection is the opposite of the probability of acceptance, the five percent rejection level is equivalent to an acceptance level of quality (ALQ) of 95 percent for material of p1 quality, i.e., five percent AQL is the complement of 95 percent ALQ.

E. OPERATING CHARACTERISTIC CURVES

The operating characteristic (OC) curve is a graph which shows producer and consumer risks in the use of a particular sampling plan. It shows graphically the way a specified sampling plan operates as the incoming quality level of material varies. An ideal operating characteristic curve is

shown in Figure 1 for $p1 = 0.025$. All lots submitted for inspection with a proportion defective (p) less than or equal to p1 have a probability of acceptance (Pa) equal to one, and those lots with proportion defective greater than p1 have Pa equal to zero. Probability of acceptance is plotted on the vertical axis and incoming quality on the horizontal axis of the graph. It is desirable to have an OC curve as near to this ideal shape as possible consistent with practicality and economy. Unfortunately a z-shaped OC curve is attainable only by perfect 100 percent inspection.

In actual practice, the quality of batches submitted for inspection will vary, and the sampling plan will reject a higher percentage of "bad" quality lots and accept more of the "good" quality lots. As a result, sampling inspection will improve the overall quality of material inspected.

Every sampling plan has a unique OC curve with its shape based on sample size (n), an acceptable number of defects (c), and the percentage of defects in the lot (p). Material containing no defectives is always accepted regardless of the value of c. Lots with 100 percent defectives are always rejected. All OC curves therefore include the points ($p = 0$, $Pa = 1$) and ($p = 1, Pa = 0$).

The two most important points on the OC curve are the probabilities of acceptance at p1 and p2. Given these two points, $(p1, 1-\alpha)$ and $(p2, \beta)$, a sampling plan and its associated

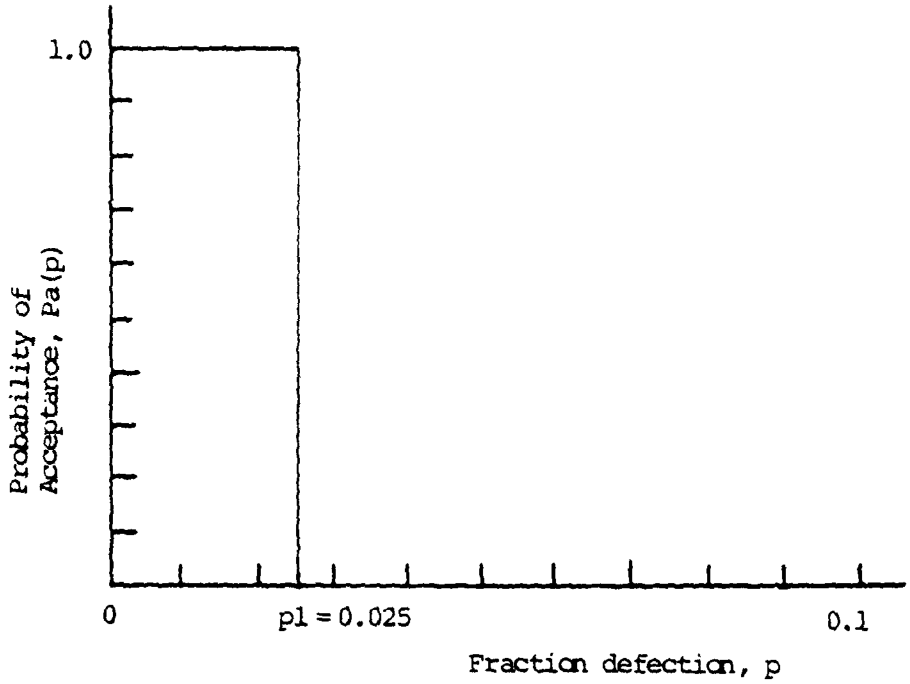


Figure 1. Ideal OC Curve

OC curve can be determined which provides the specified protection to both the consumer and the producer.

F. ACCEPTANCE SAMPLING BY ATTRIBUTES

Acceptance sampling is applicable to environments where there is a consumer-producer relationship. Acceptance sampling by attributes classifies a lot as conforming or not conforming to a specified standard. An attribute is a qualitative characteristic and grades material as "good" or "bad" or nondefective or defective.

Duncan [Ref. 5] emphasizes

> that the purpose of acceptance sampling is to determine a course of action, not estimate lot quality. Acceptance sampling prescribes a procedure that, if applied to a series of lots, will give a specified risk of accepting lots of given quality. In other words, acceptance sampling yields quality assurance.

Thus, acceptance sampling improves the quality of material in a process by encouraging "good" quality by a high rate of acceptance and discouraging "bad" quality by a low rate of acceptance. "Attributes sampling plans have the advantage of greater simplicity, of being applicable to either single or multiple quality characteristics, and of requiring no knowledge about the distribution of the continuous measurement of any of the quality characteristics" [Ref. 6].

1. Single Sample Plans

In a single sampling plan, a sample is taken from a lot and a decision to reject or accept the lot is made based on the inspection results of that sample. More specifically,

a single sampling procedure can be described in most industrial applications by only two numbers: the sample size (n) and the acceptance number (c). By taking a sample of size n, and determining the number of defectives (d), an estimate of the quality of material inspected is given by $\hat{p} = d/n$. The lot is rejected if $\hat{p}$ is greater than c/n. Although this procedure uses an estimate of lot quality ($\hat{p}$), it is again emphasized that the single sample plan's primary purpose is to determine whether to accept or to reject the lot.

As stated above, by specifying the points (p1,1-α) and (p2,β), an n and c can be found such that the OC curve passes through these two points. Finding a single sampling plan to pass through these two points exactly may be impossible since both n and c must be integer values. For p1 = 0.025, p2 = 0.10, α = 0.05, and β = 0.10, using Table 13.13 in Bowker and Lieberman [Ref. 7], a single sampling plan based on the Poisson approximation to the binomial distribution is given by c = 5 and n = 105. The OC curve for this plan is shown in Figure 2. Military Standard (MILSTD) 105D [Ref. 8] contains OC curves for various single sampling plans. MILSTD 105D is a combination of standard military sampling plans designed to have certain characteristics, i.e., specified values of p1, p2, α, and β. It is indexed by AQLs from 0.10 percent to 10 percent. It is widely used in industry as well as in government.

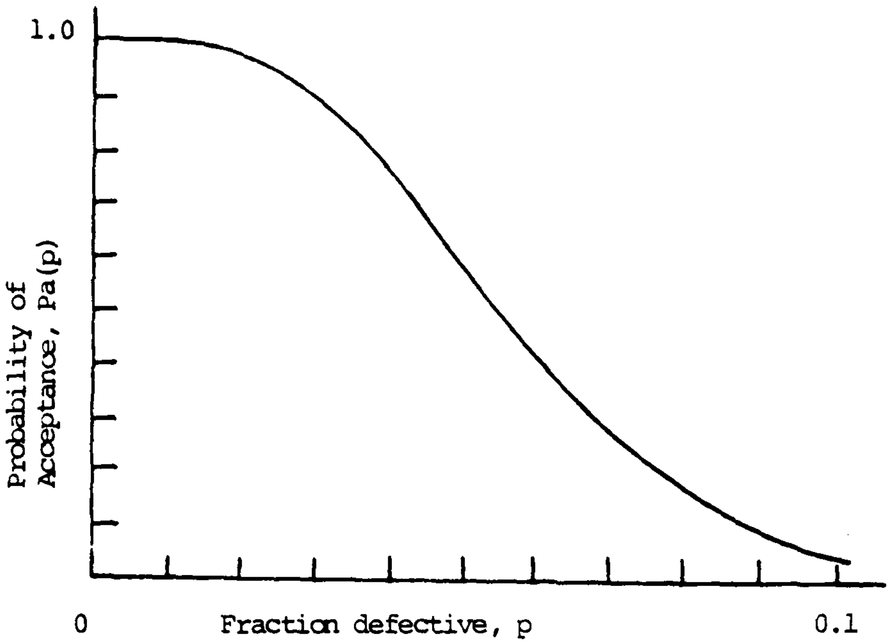


Figure 2. OC Curve for Single Sample Plan, c = 5, n = 105

2. Sequential Sample Plans

In single sampling plans the number of items sampled (n) is fixed by the plan. In sequential sampling systems there are no fixed sample sizes. Single items are inspected at random and after each inspection a decision is made to accept the lot, to reject the lot, or to continue to inspect. The primary advantage of using a sequential sampling plan is that it will usually result in a smaller sample than an equivalent single sampling plan.

A sequential sampling plan is defined by the producer's risk (α), the AQL (p1), the consumer's risk (β) and the LTPD (p2). The concept of a sequential probability ratio test (SPRT) was developed by Abraham Wald [Ref. 9]. A graphical presentation of an item-by-item sequential sampling plan for $\alpha = 0.05$, $p1 = 0.025$, $\beta = 0.10$, and $p2 = 0.10$ is shown in Figure 3. The horizontal axis is the total number of units drawn and the vertical axis is the total number of defectives drawn. If the graphical method is used, cumulative sample results are successively plotted on a sequential sampling chart. If the cumulative results are on or below the lower line, the lot is accepted. If the cumulative results are on or above the upper line, the lot is rejected. If neither of these conditions are satisfied, another item is inspected. Using the requirements given above for α, p1, β, and p2, the equations for the acceptance line and rejection line can be determined from the following formulas. Derivations are given in Duncan [Ref. 5].

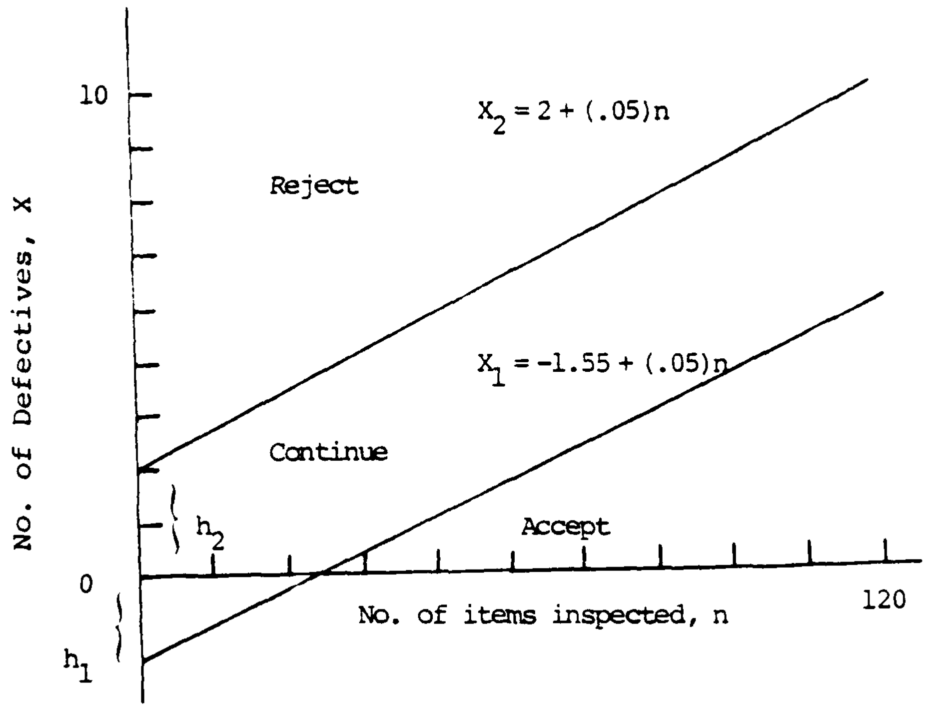


Figure 3. Sequential Sample Chart for $\alpha = 0.05$, $\beta = 0.10$, p1 = 0.025, p2 = 0.1

$$h1 = \log((1-\alpha)/\beta)/[\log(p2/p1) + \log((1-p1)/(1-p2)]$$

$$= \log((1-0.05)/0.10))/[\log(0.10/0.025) + \log((1-0.025)/(1-0.10))]$$

$$= 1.55 = \text{intercept for the acceptance line}$$

$$h2 = \log((1-\beta)/\alpha)/[\log(p2/p1) + \log((1-p1)/(1-p2))]$$

$$= \log((1-0.10)/0.05)/[\log(0.10/0.025) + \log((1-0.025)/(1-0.10))]$$

$$= 2 = \text{intercept for the rejection line}$$

$$s = \log((1-p1)/(1-p2))/[\log(p2/p1) + \log((1-p1)/(1-p2))]$$

$$= \log((1-0.025)/(1-0.10))/[\log(0.10/0.025) + \log((1-0.025)/(1-0.10))]$$

$$= 0.05 = \text{slope of the lines}$$

Substituting the values of h1 = 1.55, h2 = 2, and s = 0.05 into the following equations yield:

$$x1 = (-h1) + s*n$$

$$= (-1.55) + 0.05*n = \text{number of defectives for acceptance}$$

$$x2 = h2 + s*n$$

$$= 2 + 0.05*n = \text{number of defectives for rejection}$$

While the graphical presentation in Figure 3 can be used as the sampling plan, it is generally more convenient to use the format shown in Table I. Acceptance numbers (x1) and rejection numbers (x2) are calculated by substituting values of n into the equations for the acceptance and rejection lines. For example, the computations for n = 47 are:

$$x1 = (-1.55) + (0.05)*n$$

$$= (-1.55) + (0.05)*(47) = 0.8$$

$$x2 = 2 + (0.05)*n$$

$$= 2 + (0.05)*(47) = 4.35$$

Table I

Sequential Sample Plan for $p1 = 0.025$, $p2 = 0.10$, $\alpha = 0.05$, and $\beta = 0.10$

No. of Units Inspected (n)	Acceptance No. (x1)	Rejection No. (x2)
1	a	b
3	a	3
19	a	4
29	0	4
38	0	5
47	1	5
56	1	6
65	2	6
74	2	7
84	3	7
93	3	8
102	4	8
111	4	9
120	5	9

a = acceptance not possible
b = rejection not possible

Since both x1 and x2 must be integers, the acceptance number is the next integer above x1, and the rejection number is the next integer above x2. As seen in Table I for n = 47, x1 = 1, and x2 = 5. Therefore, in a sample of 47 items if the number of defects is zero or one, accept the lot. If the number of defects is five or more, reject the lot, and if the number of defects is two, three, or four, then continue sampling.

Theoretically, a sample could be continued indefinitely in this manner. In practice, the sample size (n) required to make a decision seldom exceeds two times the average sample number (ASN) when incoming material quality is equal to the AQL. Schrock [Ref. 10] The ASN is the "number of items that may be expected in the long run to be inspected per lot by the sampling plan." Bowker and Lieberman [Ref. 7] For practical reasons, sampling is generally terminated at an arbitrary point and a decision is made whether to accept or reject the lot, or no decision is made at all. If the lot is accepted at that point, consumer's risk increases slightly, whereas, if the lot is rejected, producer's risk increases slightly.

Formulas for the probability of acceptance (Pa) (OC curve points) and the average sample number (ASN) at five values of incoming fraction defective (p) are as follows:

p	Pa(p)	ASN(p)
0	1	h1/s
p1	1-α	((1-α)*h1-α*h2)/(s-p1)
s	h2/(h1+h2)	(h1*h2)/(s*(1-s))
p2	β	((1-β)*h2-β*h1)/(p2-s)
1	0	h2/(1-s)

Recall that s is the slope of the acceptance and rejection lines. These five points can be used to make adequate graphs of OC curve in Figure 4 and ASN curve in Figure 5. If more points are desired refer to Duncan [Ref. 5]. From the above it is seen that ASN's are lowest for lots consisting of very good or very poor material and highest for lots consisting of material of marginal quality.

3. Comparison of Sequential and Single Sample Plans

Comparisons between attribute sampling plans are valid only when the plans have essentially the same OC curves. The OC curve assesses the protection given to the producer and consumer by the sampling plan. It is common to match OC curves at the points $(p1, 1-\alpha)$ and $(p2, \beta)$ and then assume that other parts of the curve deviate only slightly. Duncan [Ref. 5] states: "If the OC curves of two acceptance sampling plans match reasonably well, their relative efficiency with respect to the amount of sampling required may be determined by comparing the ASNs at p1, but comparisons may also be made at other points." Figure 6 and Table II provide a comparison between the item-by-item sequential plan and the single sample plan. These plans coincide exactly at $(p1, 1-\alpha) = (0.025, 0.95)$, but because of the requirement for integer values of c and n, do not coincide exactly at $(p2, \beta)$. Further it is seen that the single sample plan is slightly more severe on the producer at intermediate points.

The ASN curve gives an indication of the anticipated costs of inspection. Figure 7 and Table II clearly show that

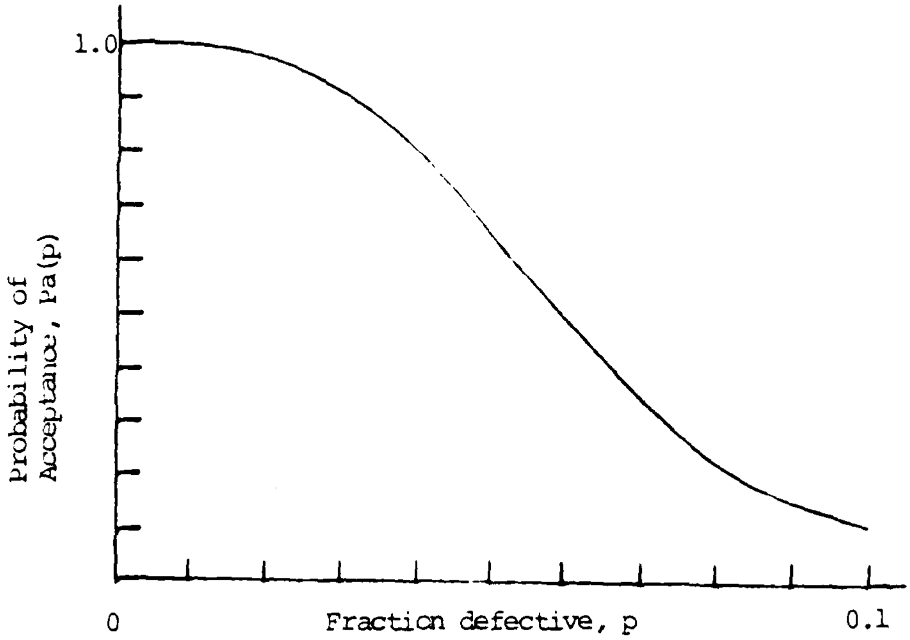


Figure 4. OC Curve for Sequential Sample Plan for
$\alpha = 0.05$, $\beta = 0.10$, p1 = 0.025, p2 = 0.1

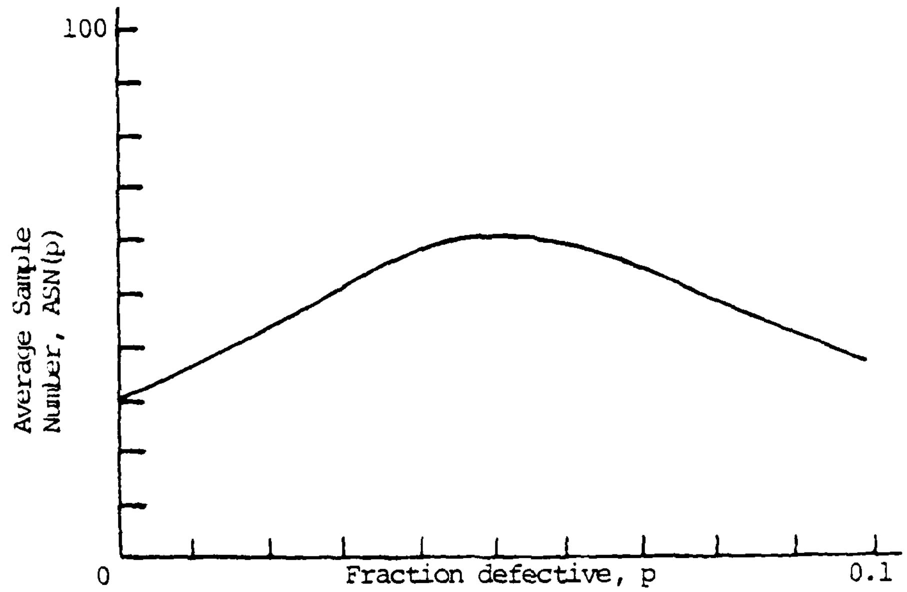


Figure 5. ASN Curve for Sequential Sample Plan for
$\alpha = 0.05$, $\beta = 0.10$, p1 = 0.025, p2 = 0.1

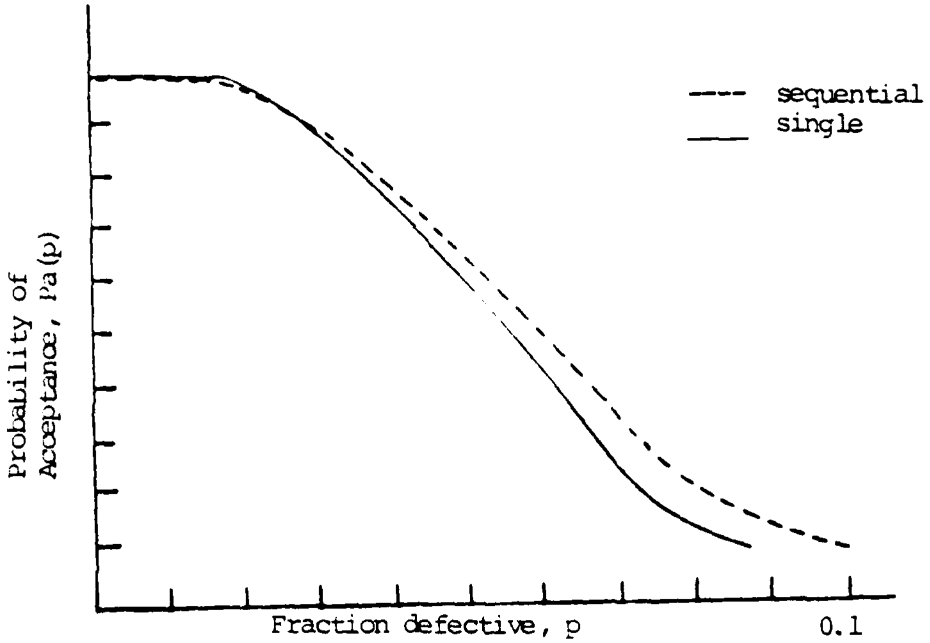


Figure 6. OC Curve Comparison of Sequential vs Single Sample Plan

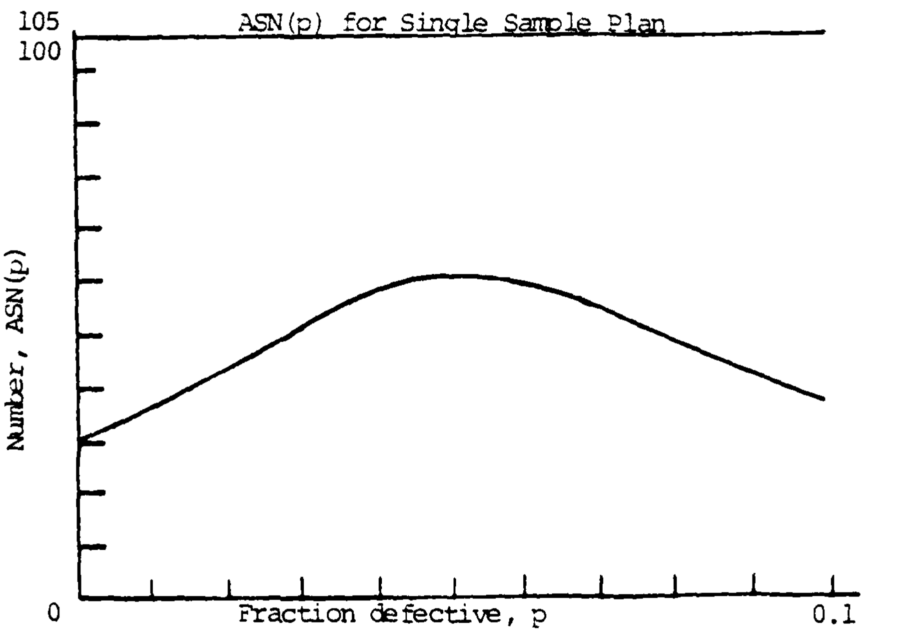


Figure 7. Comparison of ASN Curve for Single Sample Plan and Sequential Sample Plan for $\alpha = 0.05$, $\beta = 0.10$, $p1 = 0.025$, $p2 = 0.1$

Table II

Comparison of Single and Sequential Plans at OC Curve and ASN Curve Points

	Single		Sequential	
Pa	p	ASN(p)	p	ASN(p)
0.995	0.015	105	0.012	36
0.990	0.017	105	0.015	38
0.975	0.021	105	0.020	42
0.950	0.025	105	0.025	46
0.900	0.030	105	0.031	52
0.750	0.040	105	0.043	58
0.500	0.054	105	0.058	58
0.250	0.071	105	0.077	49
0.100	0.088	105	0.100	36
0.050	0.100	105	0.117	29
0.025	0.111	105	0.135	24
0.010	0.125	105	0.156	20

the major advantage of the item-by-item sequential sampling plan is that the ASN is everywhere significantly smaller than the sample size under a single sampling plan.

At p1 = 0.025 the sequential sampling plan reduces sampling costs by (1 - 46/105) or 56 percent as compared with single sampling.

Besides the comparisons mentioned, there are other factors to be considered which influence the choice of a sampling plan. Advantages of single sampling as compared to sequential sampling plans include fixed sample size, a reasonably accurate estimate of lot quality, and a limited amount of administration. Advantages of sequential sampling plans include reduced sampling costs and lower ASN. The efficiency of Sequential Sampling for Attributes is discussed further in Hamaker [Ref. 11].

G. ESTIMATION OF PROPORTION DEFECTIVE

As stated earlier in Section II, one significant advantage of attribute sampling is that it requires no knowledge about the statistical distribution of continuous measurements of any quality characteristic. For instance, in sampling of process times by attributes it is appropriate to record a process time as either meeting an established standard or exceeding it. Suppose T is a process time and t is an established processing time standard or limit for a requisition. Then the population of all requisitions can be divided into two groups on the basis of this characteristic: those which have requisition process times that meet the standard and those which do not.

In order to estimate the proportion defective, p, suppose n requisitions are sampled from a process. Let $T(1)$, $T(2)$, ..., $T(n)$ be the independent process times for those n requisitions. Then $p = P[T(i) > t]$, $i = 1, 2, \ldots, n$, is the probability that the actual individual processing time, $T(i)$, is greater than the process time limit, t. Now let $X(i) = 1$ if $T(i) > t$ (requisition i exceeds process time limit (Group A)), and let $X(i) = 0$ if $T(i) < t$ (requisition i within process time limit (Group B)). Then $p = P[X(i) = 1] = P[T(i) > t]$, $i = 1, 2, \ldots, n$. Let S be the sum of the assigned numbers $X(i)$. Note further that S is in fact the sum of the 0's and 1's and can be interpreted as the number of requisitions which exceed the process time limit, t, in a sample of size n. X itself is distributed binomially and its mean, $\overline{X} = S/n$, is the proportion

of the sample belonging to Group A, and is an estimate of the proportion defective, $\hat{p}$, for the process. The sampling distribution of the mean from any population with finite variance is approximately normal for large sample sizes. The sample variance of the sample distribution is σ^2/n. Formulas yielding the population mean, μ, and the population variance, σ^2, for a population containing a proportion p of 1's and a proportion (1-p) of 0's are $\mu = p$ and $\sigma^2 = p*(1-p)$. It is emphasized that for small n or for values of $p < 0.1$ that the normal approximation is an inexact method.

H. CONFIDENCE INTERVALS FOR PROPORTION DEFECTIVE

In Section II.G. it was shown that for large lot sizes, $\hat{p} = S/n$ is an approximation for the proportion of defective items, p, in the lot. Although managers frequently want a single point estimate for a lot or process value, it is often desirable to determine an interval that will have a high probability of containing the population value.

When the product of n and p is greater than five, the $100*(1-\alpha)$ percent confidence interval is given by

$$\hat{p} \pm Z_{\alpha/2}\sqrt{\frac{\hat{p}(1-\hat{p})}{n}}$$

where $Z_{\alpha/2}$ is the $\alpha/2$ percentage point obtainable from tables of the normal distribution.

When the product of n and p is less than five, the Poisson approximation to the binomial distribution is used to set up

confidence limits on p utilizing the Dodge-Romig chart in Duncan [Ref. 5]. For example, suppose $p = 0.02$ and $n = 100$, i.e., there were 2 defective items out of 100. For $\alpha = 0.05$, to get an upper 0.95 confidence limit for p, enter the Dodge-Romig chart at the vertical ordinate $\alpha/2 = 0.05/2 = 0.025$, proceed to the curve $X = 2$, and read off the x-axis $p^*n = 3.95$. Then the upper limit for p would be $3.95/100 = 0.0395$. To get the lower 0.95 confidence limit for p, enter the Dodge-Romig chart at the vertical ordinate $(1-\alpha/2) = (1-0.05/2) = 0.975$, proceed to the curve $X = 1$ and read off the x-axis $p^*n = 0.24$. Then the lower limit would be $0.24/100 = 0.0024$. The interval 0.0024 to 0.0395 would thus form a 0.95 confidence interval for the value of p. This interval has a probability of 0.95 of covering the population value. Confidence limits using this latter method generally pertain more to quality control applications because of the desire for small proportion defective, p.

III. CURRENT NAVSUP QUALITY CONTROL PROGRAM

The current Naval Supply Systems Command (NAVSUP) Uniform Quality Control Program is described in NAVSUPINST 5220.11C of October 27, 1976, with changes incorporated [Ref. 12]. It contains procedures for sampling certain supply functions (material flow) and performance reporting (process times), with NAVSUP-established standards for acceptable levels of quality (ALQ), along with reporting requirements.

A. CURRENT SAMPLING PROCEDURES FOR INSPECTION OF MATERIAL FLOW

NAVSUP directs that the MILSTD 105D be utilized in sampling procedures for inspection by attributes. These procedures are designed for the purpose of monitoring certain supply functions to determine whether material is being processed accurately within the stock point system. Table III shows the specific supply functions to be measured for quality of performance, the ALQ, and sampling frequency for each. Optional supply functions are sampled as personnel resources are available. Procedures specific to each function are contained within NAVSUPINST 5220.11C.

MILSTD 105D sampling procedures for inspection by attributes are summarized in Enclosure (2) Attachment (A) of NAVSUPINST 5220.11C. This procedure includes the following steps:

Table III

Specific Supply Functions to be Measured for Quality of Performance

FUNCTION	ACCEPTABLE LEVEL OF QUALITY (ALQ)	SAMPLING FREQUENCY
Receipts	97.5%	Monthly
Issues	97.5%	Monthly
Packing for Shipment	99.0%	Monthly
Release to Carrier	99.0%	Quarterly
Operations Accuracy*	97.5%	Monthly
Accuracy of Documentation*	99.0%	Quarterly
Frustrated Receipts*	99.0%	Quarterly
Storage Practices*	95.0%	Annually
Storage Shelf Life*	97.5%	Annually
Preservation Marking*	97.5%	Annually
Inventory*	99.0%	Quarterly

* Optional

1. The inspector specifies the ALQ for the supply function to be measured from Table III.

2. Tables are entered using inspection level II and single sample plans.

3. The monthly sample size is determined from the monthly processing rate for the supply function to be measured.

4. Normal inspection is used unless two out of five successive lots are rejected, at which time tightened inspection is introduced. Normal inspection is resumed when five consecutive monthly samples meet the stated criteria. In the NAVSUP Quality Control Program no provision is given for the situation where ten consecutive lots are under tightened inspection, or for reduced inspection.

Table IV shows the quarterly Quality Control Report for Material Flow submitted by Naval stockpoints to NAVSUP. When sampling frequency is required monthly, the quarterly report contains the cumulative figures for all three months in obtaining the percentage for quality level attained. In effect, what is reported to NAVSUP is a point estimate determined from the formula:

Table IV

Quality Control Report for Material Flow

Supply Function

(1)	Population	______
(2)	Sample size	______
(3)	Prescribed ALQ	______
(4)	Quality level attained	______
(5)	Percent Variance	______

Quality Level Attained = Number of nondefectives/Sample size

B. CURRENT SAMPLING PROCEDURES FOR INSPECTION OF PROCESS TIMES

NAVSUP currently specifies that sampling of process times occurs over a minimum two-week period and further stipulates that at least five subsamples be collected. In order to arrive at an individual subsample size, the total sample size is determined from an estimated volume of transactions processed for each supply function to be analyzed. The table in Attachment A to Enclosure 3 of NAVSUPINST 5220.11C is an excerpt of Table A-2 from "Sampling Procedures and Tables for Inspection by Variables for Percent Defective" (MILSTD 414), which is used in the NAVSUP procedure to determine sample size from estimated transaction volumes. By using this table, it is assumed that the process times for each supply function are independent identically distributed normal random variables. Once the sample size is determined, items are sampled randomly (except where 100 percent inspection is performed) and statistics are computed on the data collected.

Process times for requisition input waiting time, storage site processing, transportation hold, and referral lag time are sampled for issue priority groups I, II, and III. The statistical information provided by stockpoints in the quarterly Quality Control Report to NAVSUP is contained in Table V. Different percentiles in the table are applicable for different supply functions.

Table V

Quality Control Report of Process Times

	IPG I	IPG II	IPG III
POPULATION			
TOTAL SAMPLE SIZE			
MEAN			
STANDARD DEVIATION			
__ PERCENTILE			
NAVSUP STANDARD			

The 95th percentile is computed for requisition input waiting time, the 92nd percentile is computed for storage site processing, and the 80th percentile is computed for transportation hold. NAVSUP-established standards vary according to issue priority group being sampled.

The 95th percentile is defined as the value below which 95 percent of the distribution of values fall. The percentile is obtained by ordering the sampled data and finding the value in the ordered list where 95 percent of the items in the ordered list fall below that value. Without the aid of a

computing device, the ordering of data for large sample sizes is error-prone and time-consuming.

If the 95th percentile for a specific supply function reported exceeds the NAVSUP-established standard, that information is highlighted at NAVSUP Headquarters, and stock-point activities are required to submit documentation explaining the reasons for and planned management actions to resolve discrepant areas.

IV. PROPOSED NAVSUP QUALITY CONTROL PROGRAM

A proposed revision of the NAVSUP Quality Control Program is described below. It contains sequential analysis techniques described above in Section II.F.2. for sampling certain supply functions (material flow) and performance reporting (process times). It also specifies standards for acceptable levels of quality and the reporting requirements.

A. PROPOSED SAMPLING PROCEDURES FOR INSPECTION OF MATERIAL FLOW

Sequential sampling plans for AQL's of 0.01, 0.025, 0.05, 0.08, and 0.2 are described in Appendix A. Whereas it is straightforward to develop sequential sampling plans for other AQL's by using the formulas given in Section II.F.2., the actual plans were generated by using the TI-59 programmable calculator. Lindsay [Ref. 13] In addition to the plans themselves, the associated OC and ASN curve points are given in tabular and graphical form. Because of reduced sample sizes under the item-by-item sequential plans, it may be possible to sample all the supply functions including the optional functions listed in Table III. The actual number of times each function is to be sampled varies according to personnel resource availability.

The item-by-item sequential sampling procedure includes the following steps:

1. The ALQ for the supply function to be measured is specified in advance from Table III.

2. Items are sampled one by one and the results are recorded serially until a decision to accept or reject is possible, or until the sample termination point is reached and no decision to accept or reject has been made to that point. In practice, the inspector may sample several items in groups and base a decision on whether to accept, reject, or continue sampling at group intervals. According to Duncan [Ref. 5] the group method has minimal effect on the OC and ASN curves, but practical considerations may make this approach preferable to item-by-item sequential sampling. It may be convenient to determine group size based on the number of items sampled for a particular supply function during half-day intervals.

Under the proposed quality control program, quarterly reports to NAVSUP include the information shown in Table VI. When a decision to accept, reject, or terminate sampling is made for a particular supply function, the column entries can be recorded in Table VI, indicating sampling is terminated. The decision to accept, reject, or terminate based on no decision is analogous to the green, red, and yellow "ball" approach currently briefed at NAVSUP Quality Control meetings. The "yellow ball", or termination of sampling with no decision indicates marginal quality for that particular supply function process. Once a sample is concluded for a particular supply

Table VI

Proposed Quality Control Report for Material Flow

Supply function:

Prescribed ALQ:

	No. of Times Function Sampled					
	1	2	3	4	5	6
Sample size						
No. of Defects						
Decision*						

* A = Accept, R = Reject, N = No Decision.

function, the inspector is then available to sample other areas or to initiate a new sample on the function just concluded.

B. PROPOSED SAMPLING PROCEDURES FOR INSPECTION OF PROCESS TIMES

As mentioned above sequential sampling plans for various AQL's are described in Appendix A. These AQL values are consistent with AQL's currently prescribed by NAVSUP. Along with the plan itself, the OC and ASN curve points are given in tabular and graphical form. The same procedure as outlined in Section IV.A., applies. The theoretical basis for this approach was developed in Section II.G. Quarterly reports to NAVSUP would contain the information shown in Table VII.

C. APPLYING A SPECIFIC SEQUENTIAL SAMPLING PLAN

This section illustrates specifically how a stockpoint would sample a particular supply function. Suppose the

Table VII

Proposed Quality Control Report of Process Times

	IPG I	IPG II	IPG III
POPULATION			
TOTAL SAMPLE SIZE			
NR. WITHIN STANDARD			
MEAN			
STANDARD DEVIATION			
DECISION *			
PRESCRIBED ALQ			

* A = Accept, R = Reject, N = No Decision

quality control director at NSC Charleston desires that a sample be conducted on requisition input wait time for issue priority group (IPG) II. In this case the NAVSUP-established standard is that 95 percent of the requisitions received be entered into the computer within 12 hours. This translates to an AQL or $p1 = 0.05$. Therefore, the sampling plan in Appendix A part III is used. The inspector is asked one afternoon to sample requisitions one-by-one and to record whether or not the requisition processing standard was met for each in the sequence sampled. At the end of the afternoon the inspector returns to his director with the results. The inspector has sampled 50 items and found two defectives in that sample. The director refers to Appendix A part III and finds that he is unable to accept or reject the process based on the sample so far. He instructs the inspector to sample additional items the next morning. At noon the next day the inspector returns again with another 50 items sampled and two defectives. The cumulative results show a total of 100 items

sampled with four defectives. Reference to Appendix A part III indicates that the process for requisition input wait time for IPG II material is under control and the decision to accept is made.

Reference to Appendix A part III.B., shows that if the true process average is 0.95, i.e., a fraction defective p = 0.05, then 95 percent of the time the process for IPG II requisition input wait time will be accepted as under control based on the sample result. The average sample number (ASN) is 120; however, based on our sample results we were able to arrive at a decision earlier, i.e., after sampling only 100 items in our example.

At this point, the NSC Charleston director is free to initiate a new sample.

D. DEVELOPING A COMPLETE QUALITY CONTROL PROGRAM

This section outlines an approach to be used in establishing a complete quality control program at stockpoints. Utilizing sequential analysis all supply functions for material flow and process times could most likely be sampled within a quarterly reporting period due to the smaller sample sizes required in each functional area.

First, for each quarterly reporting period the stockpoint must designate all functional areas to be sampled along with their corresponding AQL. The NAVSUP-established AQL's currently prescribed can be used.

Second, determine from Appendix A the average sample number for the given ALQ for each supply functional area to be sampled during the quarter. If a supply function is to be sampled monthly, the ASN is multiplied by three to estimate the total number of items to be sampled in that area for the quarter.

Third, add the ASN's to arrive at a total number of items to be sampled for the quarter. Note that this total number is only a planning figure to be used in establishing workload volume.

Fourth, divide the total number of items to be sampled for the quarter by the number of workdays in the quarter to compute an estimate of the number of items to be sampled daily.

Fifth, the director assigns inspectors to sample supply functional areas as discussed in Section IV.C., above.

This outline meets the *minimum* requirements as contained in the current NAVSUP Quality Control Program. However, it allows the option to include as mandatory all supply functional areas considered optional under the existing instruction. The quality control director may find that he wishes to inspect certain areas more than others. The sequential analysis approach enables him the flexibility to increase sampling in potentially troublesome areas.

V. COMPARISON OF CURRENT AND PROPOSED QUALITY CONTROL PROGRAMS

This section compares the current NAVSUP Quality Control Program discussed in Section III with the proposed program in Section IV.

A. MATERIAL FLOW

A general comparison of single and sequential sampling plans was made in Section II.F.3. There it was seen that the major difference is that a sequential sampling plan results in smaller sample sizes on the average while maintaining protection for both the consumer and producer equivalent to that of a single sampling plan.

Under the existing NAVSUP program, it was seen in Section III that the only management information received by NAVSUP from the stockpoints is the quality level attained for each supply function sampled.

Under the existing NAVSUP program, the stockpoint has only a 50 percent chance of meeting the established standard if the true process average is equal to the ALQ. That is, when taking a random sample from a normal or other symmetric population, the probability that the sample mean exceeds the process average is 0.5. This is clearly an unacceptable risk for the producer (stockpoint). Under the proposed procedure the producer's risk can be specified so that the stockpoint will have a 95 percent chance of meeting the prescribed ALQ

if the process is under control. Conversely, the stockpoint will have a worse chance of meeting the standard if material is of poorer than established ALQ quality. Thus the consumer can be reasonably assured that the material he accepts is of good quality.

Another feature of sequential sampling is that estimates of lot sizes are not required to execute the plan as they are for single sampling plans. An example was taken from one of the quarterly reports to NAVSUP to illustrate the number of items that would be sampled monthly for receipts both under the current NAVSUP procedure and the proposed sequential analysis. For a population of 32,000 items, MILSTD 105D requires that 315 items be sampled. For the same AQL or $p1 = 0.025$, the average sample size using sequential analysis is 46. Thus sampling costs are reduced monthly for receipts sampling by $(1-46/315) = 85$ percent.

The reduced sampling required by the sequential plan, while maintaining producer and consumer protection, enables limited personnel resources to be managed more effectively. The flexibility of selecting any or all supply functions to be sampled in Table III, along with the frequency of sampling in each supply functional area, gives management the opportunity on a regular basis to ensure that the overall supply process is functioning according to established standards.

To look at an aggregate comparison, Table VIII lists all possible categories to be inspected along with their AQL and gives the total number of items that on the average would be

Table VIII

Aggregate Comparison of Sample Sizes for Supply Functions

Supply Function	p	MILSTD 105D Sample Size	Sequential ASN(p)
Receipts	0.025	500	46
Issues	0.025	800	46
Packing for Shipment	0.010	500	28
Release to Carrier	0.010	315	28
Tailgate Data Analysis	0.010	315	28
Requisition I/P Wait Time			
IPG I	0.050	315	120
IPG II	0.050	500	120
IPG III	0.050	500	120
Referral Lag Time			
IPG I	0.080	315	89
IPG II	0.080	315	89
IPG III	0.080	500	89
Storage Site Processing			
A-4, A-5			
IPG I	0.080	20	89
IPG II	0.080	80	89
IPG III	0.080	80	89
AO			
IPG I	0.080	80	89
IPG II	0.080	125	89
IPG III	0.080	200	89
Transportation Hold			
Lcl Dlvy			
IPG I	0.200	125	78
IPG II	0.200	200	78
IPG III	0.200	200	78
Surface			
IPG I	0.200	2	78
IPG II	0.200	125	78
IPG III	0.200	200	78
Air			
IPG I	0.200	80	78
IPG II	0.200	80	78
IPG III	0.200	50	78
Mail			
IPG I	0.200	80	78
IPG II	0.200	125	78
IPG III	0.200	200	78
Land			
IPG I	0.200	50	78
IPG II	0.200	80	78
IPG III	0.200	125	78
Ops Accuracy	0.025	315	46
Accuracy of Documentaion	0.010	315	28

Table VIII (Cont.)

Supply Function	p	MILSTD 105D Sample Size	Sequential ASN(p)
Frustrated Receipts	0.010	N/A	28
Storage Practices	0.050	N/A	120
Storage Shelf Life	0.025	N/A	46
Preservation Marking	0.025	N/A	46
Inventory	0.010	80	28
Totals		7,892	2,849

inspected under the current NAVSUP procedure and under the proposed sequential plan. If each supply functional area were sampled one time only the sum of the ASN's under the sequential plan totals 2849 items. Utilizing quarterly reports submitted by stockpoints to determine populations for each category in order to determine sample size from MILSTD 105D, if each supply functional area were sampled one time only, the number of items sampled under the current NAVSUP instruction would total 7,892, nearly three times as many items. That is even excluding several optional categories where data was not obtainable.

In summary, the proposed sequential sampling plan gives better protection for both producer and consumer, reduces sample size, frees limited resources and/or increases the number and frequency of supply functional areas to be inspected, and allows more management information on process control then does the current NAVSUP Quality Control Program.

B. PROCESS TIMES

It is true that variables sampling techniques have smaller ASN values than do equivalent sequential sampling plans. However, the theory behind the development of variables sampling plans, including OC curves, assumes that measurement of process times for each supply function sampled are independent identically distributed normal random variables. There is insufficient justification from empirical data to establish that process times are normal random variables. In fact,

simple histograms of process time data show a distribution that is highly positively skewed and distinctly non-normal. Since this assumption is not justified, the sample sizes obtained from MILSTD 414 are too small to afford sufficient protection to the consumer.

The current NAVSUP instruction requires that the sample value at a given percentile be less than a given standard. For example, the 92nd percentile value of a sample distribution is required to be less than or equal to an established standard of 12 hours for all referrals. Alternatively, sequential analysis can be performed with $p1 = 0.08$, $p2 = 0.15$, $\alpha = 0.05$, and $\beta = 0.10$. This approach is equivalent to the current plan only in that it allows for the same fraction defective, 0.08; however, it does not assume anything about the statistical distribution of process times, nor does it require ordering of large volumes of data as does the current plan.

To illustrate this point, an example was selected randomly from quarterly reports submitted to NAVSUP. In this example the NAVSUP standard was that 92 percent of the items were to be processed within three days. This equates to an allowable fraction defective of $p1 = 0.08$. Using the current variables sampling approach for determining sample sizes, MILSTD 414 yields a sample size for this example of 75 items. It will be shown that the OC curve for the single sample plan $c = 10$ and $n = 77$ derived from Table 13.13 of [Ref. 7] gives inadequate protection to the consumer in this example. This single sample plan yields values of $p1 = 0.08$, $p2 = 0.2$, $\alpha = 0.05$, and $\beta = 0.10$.

Table IX

OC Curve Comparison

Pa	p Single c = 10, n = 77	p Single c = 22, n = 197	p Sequential
0.995	0.056	0.064	0.060
0.990	0.062	0.068	0.065
0.975	0.071	0.074	0.073
0.950	0.080	0.080	0.080
0.900	0.091	0.087	0.088
0.750	0.112	0.100	0.101
0.500	0.139	0.115	0.115
0.250	0.169	0.132	0.132
0.100	0.200	0.149	0.150
0.050	0.220	0.158	0.163

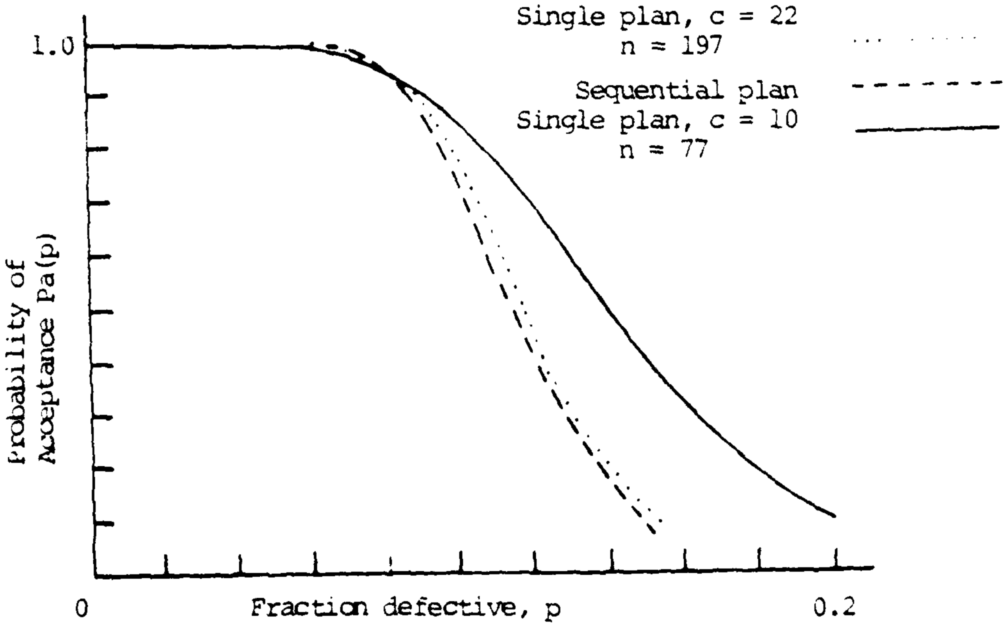


Figure 8. OC Curve Comparison

A comparison of the OC curve for these values is made with OC curves for the equivalent single and proposed sequential plans for $\alpha = 0.05$, $\beta = 0.10$, $p1 = 0.08$, and $p2 = 0.15$ in Table IX and Figure 8. It is readily seen that the OC curve points for the single plan $c = 10$ and $n = 77$ are far less stringent on the producer and this single sample plan does not provide adequate protection to the consumer. For a given probability of acceptance, Pa, the fraction defective, p, is significantly greater for the single sample plan $c = 10$ and $n = 77$ as compared with the single sampling plan $c = 22$ and $n = 197$ or the sequential plan.

VI. CONCLUSIONS AND RECOMMENDATION

Several conclusions have been reached as a result of reviewing the current NAVSUP Quality Control Program and the existing theory on quality control:

First, currently any stockpoint sample of material flow has only a 50 percent chance of meeting prescribed NAVSUP standards if the process average is equal to the ALQ. A properly implemented attributes sampling plan specifying p1, p2, α, and β, rewards good performance by the stockpoint with a high probability of acceptance and penalizes poor performance by the stockpoint with a low probability of acceptance. The attributes sampling plan then provides protection to both the consumer (NAVSUP) and the producer (stockpoint).

Second, under the current system transaction volumes are estimated before a sample size can be determined. MILSTD 105D is used only to determine sample size in the NAVSUP procedure, and is not used for the purpose for which it was designed, i.e., to determine a complete sampling plan scheme.

Third, MILSTD 414 is inappropriate for use in sampling process times because they are not normal random variables.

Fourth, no attributes sampling plan with the same two points on the OC curve can have a smaller ASN at those points than a sequential sampling plan. Attributes sampling plans require no assumption about the distribution of the population.

In light of the conclusions reached above, it is recommended that NAVSUP adopt a Quality Control Program utilizing sequential sampling techniques for both material flow and process times. The sequential sampling approach proposed here enables all current and/or additional supply areas to be inspected on a recurring basis even with current limited personnel resources, affords greater protection to both the stockpoint and NAVSUP, eliminates the requirement to estimate transaction volumes to determine sample sizes, eliminates the need for manual ordering of large volumes of data in order to determine values at various percentiles, and requires no assumption about the statistical distribution of the data being sampled.

APPENDIX A

I. Sequential Sample Plan for p1 = 0.01, p2 = 0.10, α = 0.05, β = 0.10, h1 = .939, h2 = 1.205, and s = 0.03975. (ALQ = 99%)

A. SAMPLE PLAN

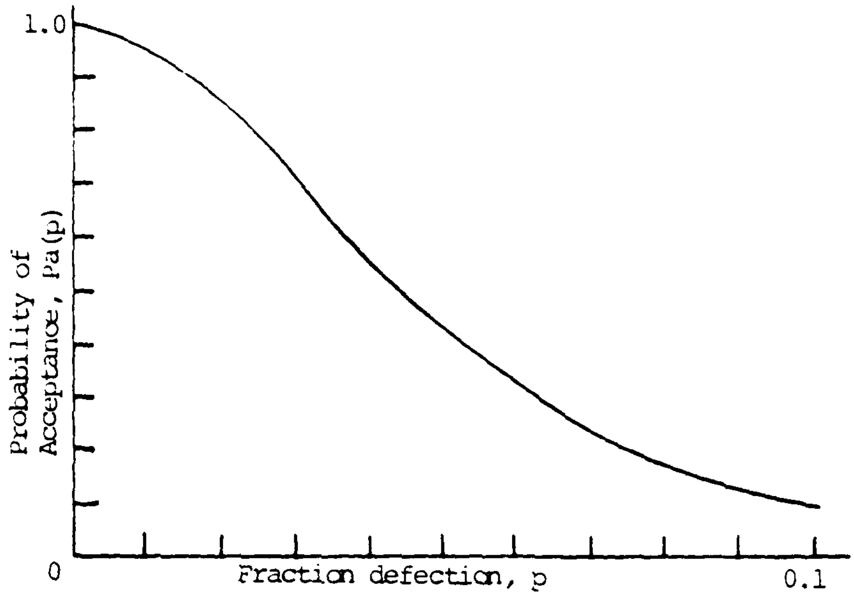
No. of Units Inspected (n)*	Acceptance No.	Rejection No.
1	a	b
2	a	2
20	a	3
24	0	3
46	0	4
49	1	4
71	1	5
74	2	5
96	2	6
100	3	6

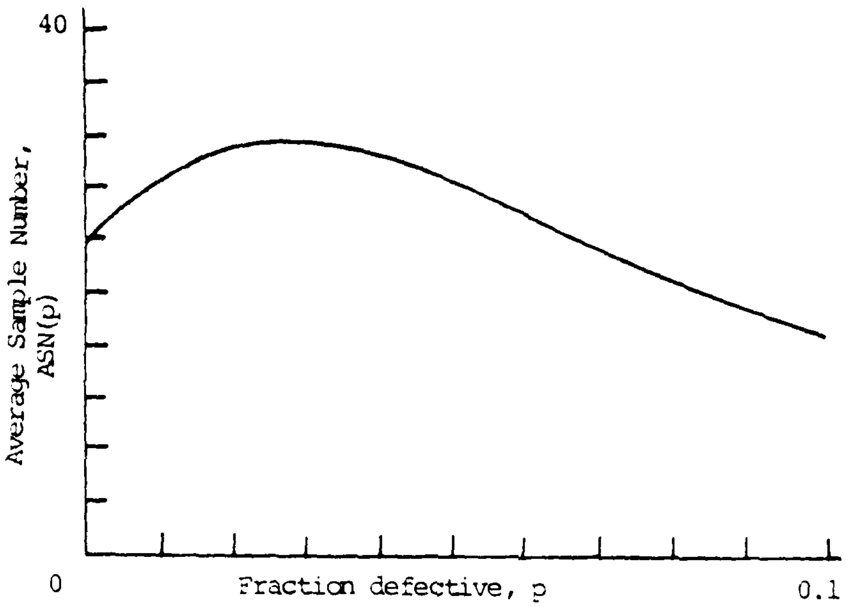
a = acceptance not possible
b = rejection not possible
* If there is no entry for the number of items sampled (n), refer to the table entry less than the actual number sampled. Sample Procedure: Sample item-by-item until criteria are met for acceptance or rejection, or discontinue sampling at termination point = 56 with no decision.

B. OC and ASN Curve Points

FRACTION DEFECTIVE (p)	P(ACCEPT,p)	ASN (p)
0.002	0.997	25
0.004	0.987	26
0.010	0.950	28
0.018	0.863	31
0.035	0.624	31
0.045	0.499	29
0.073	0.224	22
0.100	0.100	17
0.129	0.042	13
0.175	0.011	9

C. Graphs of OC and ASN Curves





II. Sequential Sample Plan for p1 = 0.025, p2 = 0.10, α = 0.05, β = 0.10, h1 = 1.535, h2 = 1.971, and s = 0.0549. (ALQ = 97.5%)

A. SAMPLE PLAN

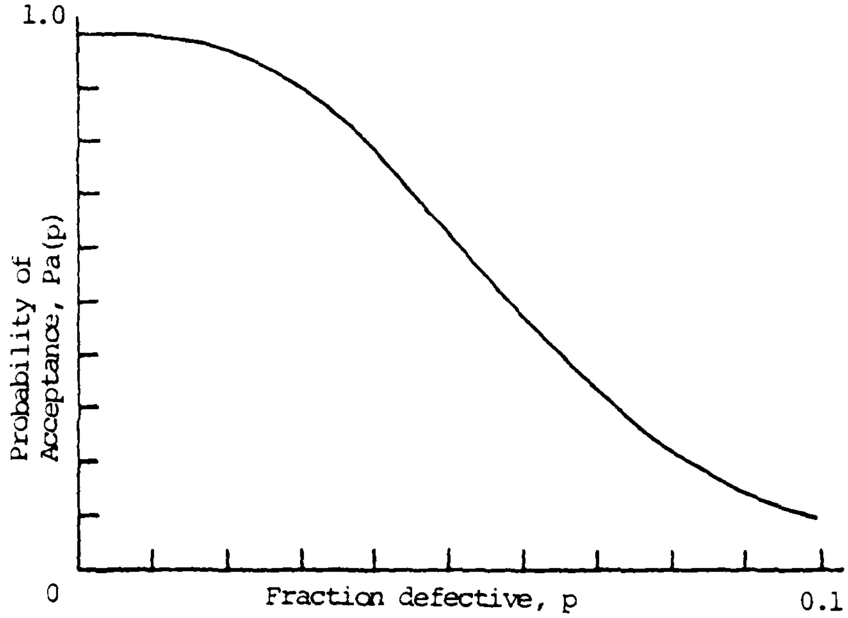
No. of Units Inspects (n)*	Acceptance No.	Rejection No.
1	a	b
3	a	3
19	a	4
29	0	4
38	0	5
47	1	5
56	1	6
65	2	6
74	2	7
84	3	7
93	3	8
102	4	8
111	4	9
120	5	9
129	5	10
139	6	10

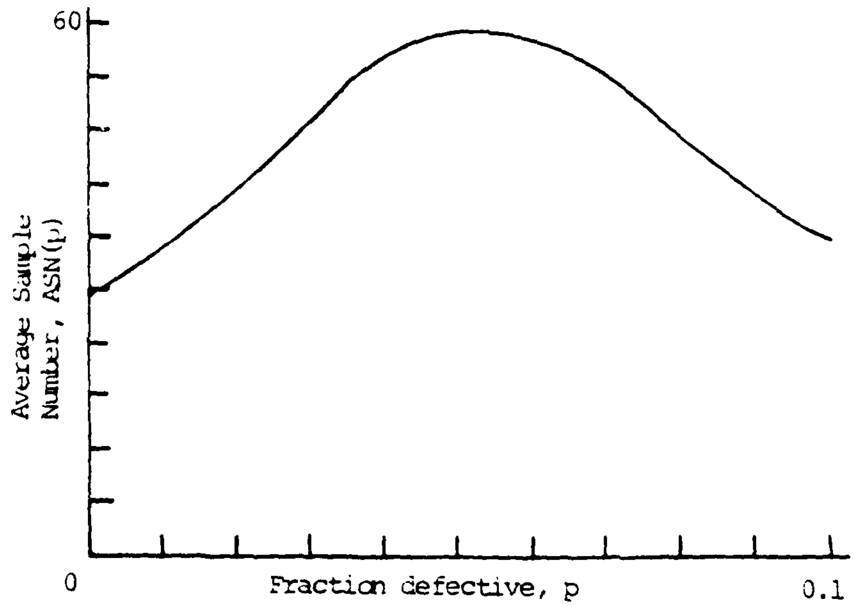
a = acceptance not possible
b = rejection not possible
* If there is no entry for the number of items sampled (n), refer to the table entry less than the actual number sampled. Sample Procedure: Sample item-by-item until criteria are met for acceptance or rejection, or discontinue sampling at termination point = 93 with no decision.

B. OC and ASN Curve Points

FRACTION DEFECTIVE (p)	P(ACCEPT p)	ASN (p)
0.010	0.997	35
0.016	0.987	39
0.025	0.950	46
0.035	0.863	54
0.051	0.624	59
0.059	0.499	58
0.080	0.224	47
0.100	0.100	36
0.122	0.042	28
0.145	0.017	22

C. Graphs of OC and ASN Curves





III. Sequential Sample Plan for $p1 = 0.05$, $p2 = 0.10$, $\alpha = 0.05$, $\beta = 0.10$, $h1 = 3.013$, $h2 = 3.868$, and $s = 0.072$. (ALQ = 95%)

A. SAMPLE PLAN

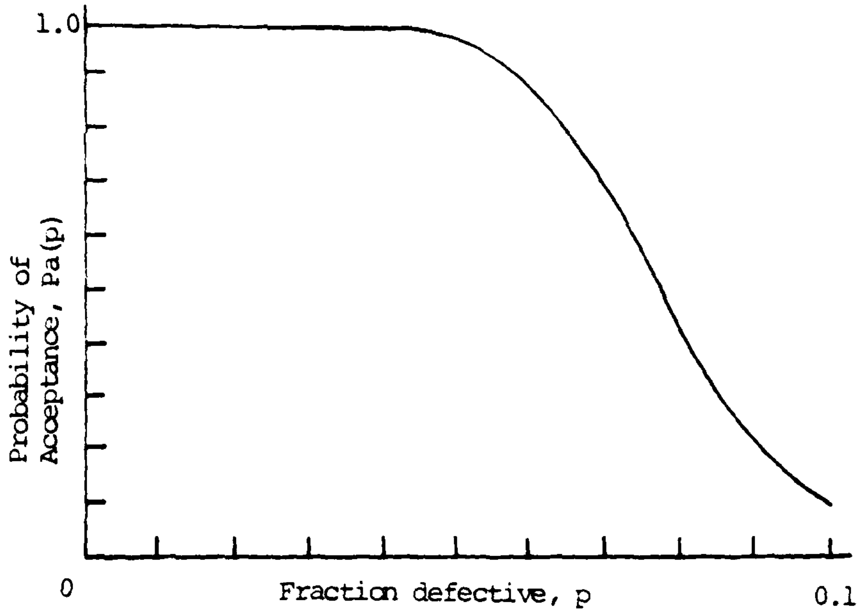
No. of Units Inspected (n)*	Acceptance No.	Rejection No.
1	a	b
5	a	5
16	a	6
30	a	7
42	0	7
44	0	8
56	1	8
58	1	9
70	2	9
71	2	10
84	3	10
85	3	11
97	4	11
99	4	12
111	5	12
113	5	13
125	6	13
127	6	14
139	7	14
141	7	15
153	8	15
154	8	16
167	9	16
168	9	17
180	10	17
182	10	18
194	11	18
196	11	19
208	12	19
210	12	20

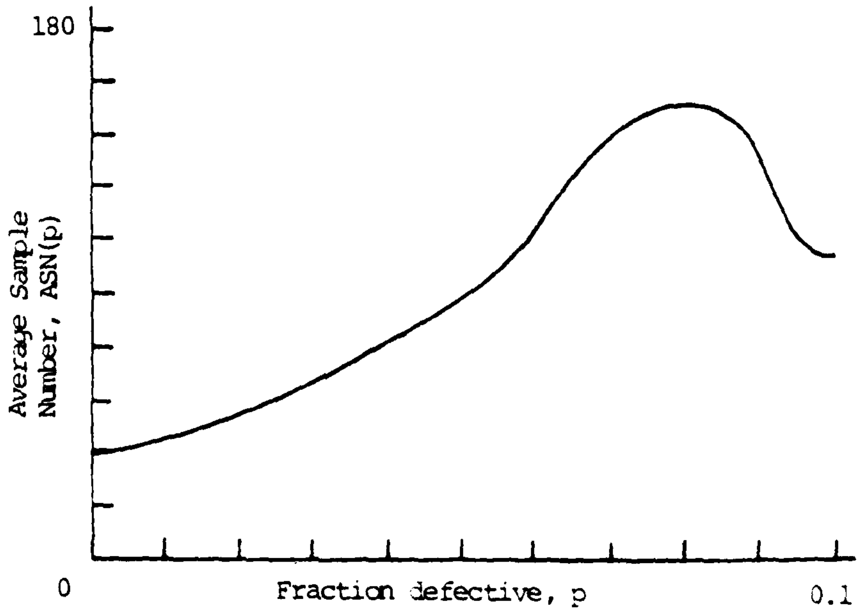
a = acceptance not possible
b = rejection not possible
* If there is no entry for the number of items sampled (n), refer to the table entry less than the actual number sampled. Sample Procedure: Sample item-by-item until criteria are met for acceptance or rejection, or discontinue sampling at termination point = 180 with no decision.

B. OC and ASN Curve Points

FRACTION DEFECTIVE (p)	P(ACCEPT|p)	ASN(p)
0.030	0.997	77
0.040	0.991	89
0.050	0.950	120
0.058	0.863	148
0.068	0.683	171
0.078	0.436	170
0.088	0.224	146
0.100	0.100	116
0.119	0.027	80
0.132	0.011	64

C. Graphs of OC and ASN Curves





IV. Sequential Sample Plan for $p1 = 0.08$, $p2 = 0.15$, $\alpha = 0.05$, $\beta = 0.10$, $h1 = 3.181$, $h2 = 4.084$, and $s = 0.112$. (ALQ = 92%)

A. SAMPLE PLAN

No. of Units Inspected (n)*	Acceptance No.	Rejection No.
1	a	b
5	a	5
9	a	6
18	a	7
27	a	8
29	0	8
36	0	9
38	1	9
44	1	10
47	2	10
53	2	11
56	3	11
62	3	12
65	4	12
71	4	13
74	5	13
80	5	14
83	6	14
89	6	15
92	7	15
98	7	16
100	8	16
107	8	17
109	9	17
116	9	18
118	10	18
125	10	19
127	11	19
134	11	20
136	12	20
143	12	21
145	13	21
152	13	22
154	14	22
161	14	23
163	15	23
170	15	24
172	16	24
179	16	25
181	17	25

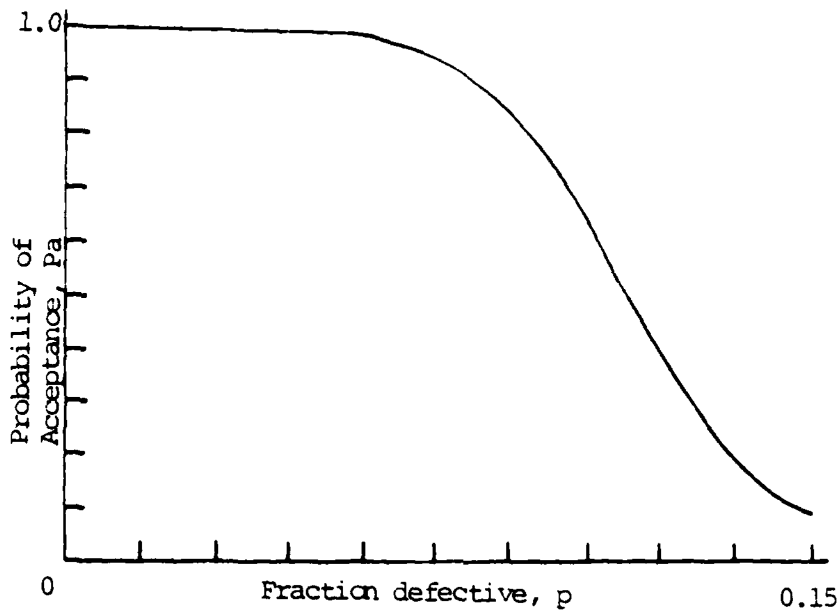
a = acceptance not possible
b = rejection not possible

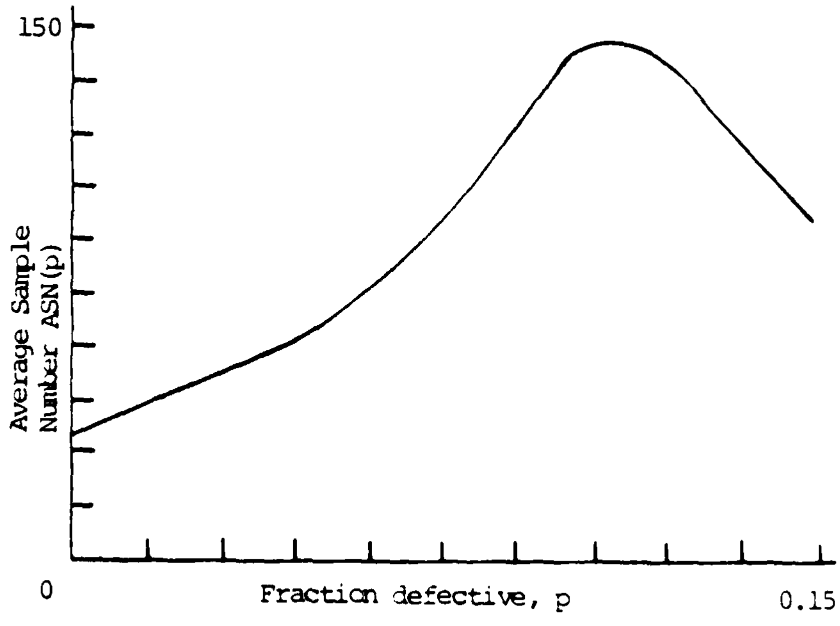
* If there is no entry for the number of items sampled (n), refer to the table entry less than the actual number sampled. Sample Procedure: Sample item-by-item until criteria are met for acceptance or rejection, or discontinue sampling at termination point = 180 with no decision.

B. OC and ASN Curve Points

FRACTION DEFECTIVE (p)	P(ACCEPT|p)	ASN (p)
0.055	0.997	56
0.064	0.991	66
0.080	0.950	89
0.092	0.863	110
0.105	0.683	128
0.119	0.436	129
0.134	0.224	111
0.150	0.100	88
0.176	0.027	62
0.193	0.011	50

C. Graphs of OC and ASN Curves





V. Sequential Sample Plan for $p1 = 0.2$, $p2 = 0.3$, $\alpha = 0.05$, $\beta = 0.10$, $h1 = 4.176$, $h2 = 5.236$, and $s = 0.247$. (ALQ = 80%)

A. SAMPLE PLAN

No. of Units Inspected (n)*	Acceptance No.	Rejection No.
8	a	8
11	a	9
15	a	10
17	0	10
19	0	11
21	1	11
23	1	12
25	2	12
27	2	13
29	3	13
31	3	14
34	4	14
35	4	15
38	5	15
39	5	16
42	6	16
43	6	17
46	7	17
47	7	18
50	8	18
52	8	19
54	9	19
56	9	20
58	10	20
60	10	21
62	11	21
64	11	22
66	12	22
68	12	23
70	13	23
72	13	24
74	14	24
76	14	25
78	15	25
80	15	26
82	16	26
84	16	27
86	17	27
88	17	28
90	18	28
92	18	29
94	19	29
96	19	30

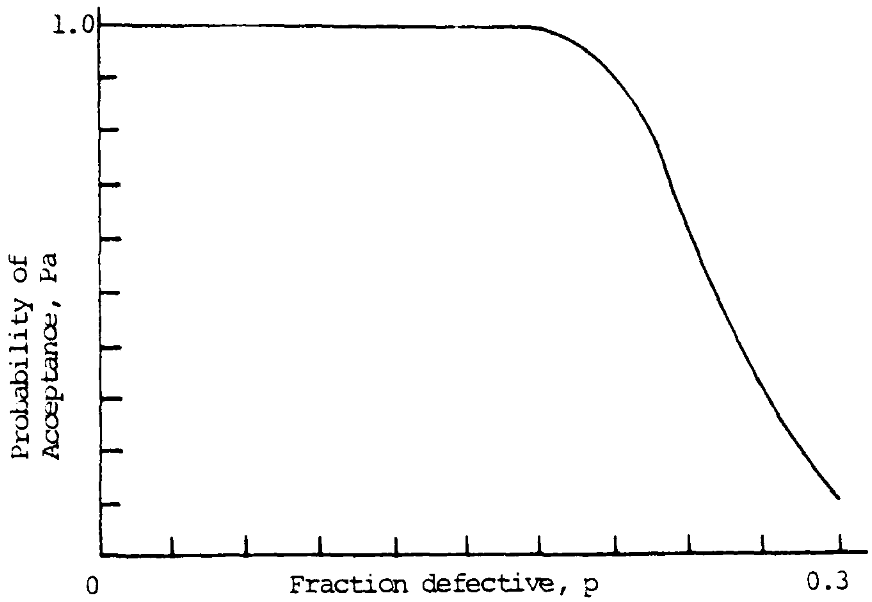
98	20	30
100	20	31
102	21	31
104	21	32
106	22	32
108	22	33
110	23	33
112	23	34
114	24	34
116	24	35
118	25	35
120	25	36
122	26	36
124	26	37
126	27	37
128	27	38
130	28	38
132	28	39
134	29	39
136	29	40
138	30	40
140	30	41
142	31	41
144	31	42
147	32	42
148	32	43
151	33	43
152	33	44
155	34	44
156	34	45
159	35	45

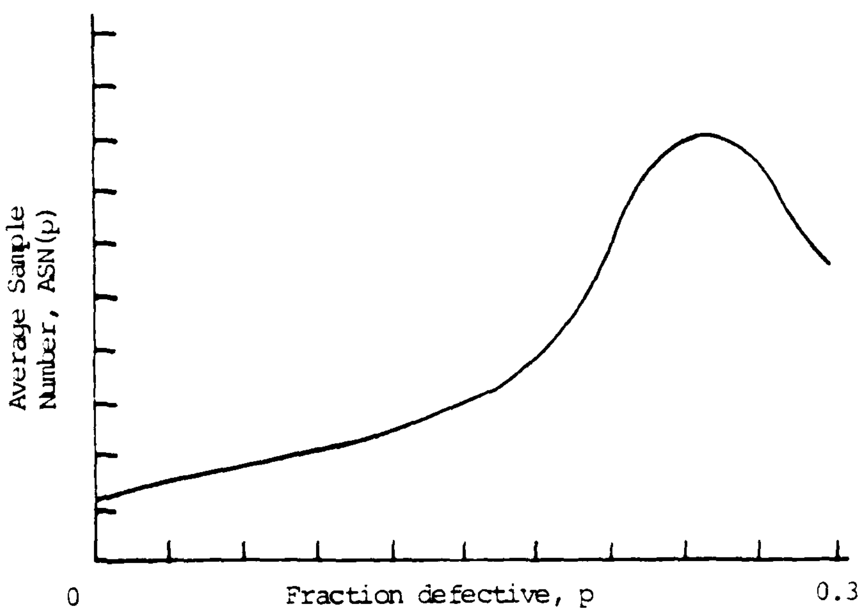
a = acceptance not possible
b = rejection not possible
* If there is no entry for the number of items sampled (n), refer to the table entry less than the actual number sampled. Sample Procedure: Sample item-by-item until criteria are met for acceptance or rejection, or discontinue sampling at termination point = 156 with no decision.

B. OC and ASN Curve Points

FRACTION DEFECTIVE (p)	P(ACCEPT|p)	ASN (p)
0.157	0.997	57
0.174	0.991	56
0.200	0.950	78
0.218	0.863	99
0.237	0.683	117
0.243	0.624	119
0.253	0.498	121
0.279	0.224	105
0.289	0.151	95
0.300	0.100	85

C. Graphs of OC and ASN Curves





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